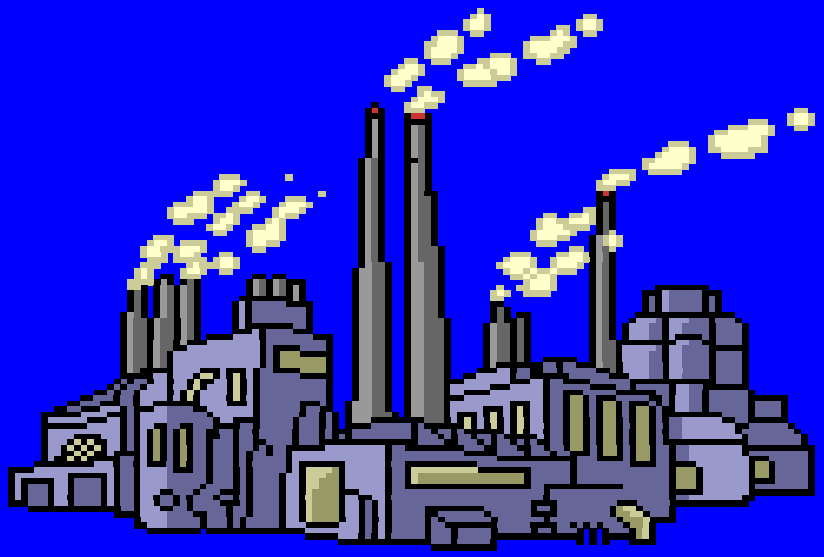
US Army Corps of Engineers®

Concrete Mix Design Considerations

Presented by: Mr. Gene Gutierrez, Albuquerque District

Mr. Richard Donovan, P.E., TSMCX

Cementitious Materials



Cementitious Materials

- Cement
- Fly Ash
- Manufacturer's Certification of Compliance
- Mill Test Reports

Cementitious Materials

- Pre-Construction Testing
- QA Testing
- Waybills and Delivery Tickets

Cement

- ASTM C 150
  - Type I, Low Alkali
- Maximum Temperature : 65 º C (150º F)

Blended Cements

- Blended Cement
  - ASTM C 595
  - Type IP (15-40%), (Pozzolan)
  - Type IS (25-75%), (Slag)
- Technical Support Available

Fly Ash

- Finely Divided Residue From Coal Combustion
- Composition Varies With Coal Source
  - Class F: Anthracite, Bituminous
  - Class C: Subbitunimous, Lignite
    - Setting Properties

Fly Ash (Pozzolan)

- ASTM C 618, Class F
- LOI: NTE 3%
- CaO: NTE 8% (ASR Mitigation)
- Optional Requirements

  (TABLE 1A and 2A)

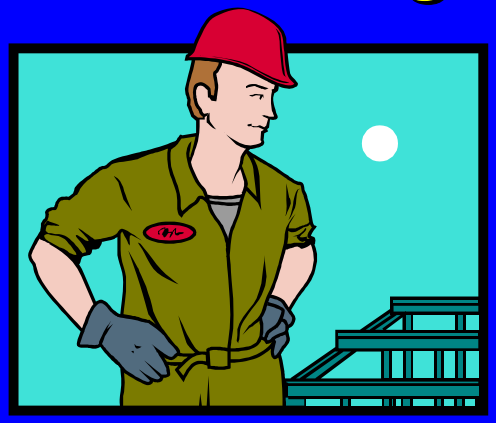
Fly Ash (Pozzolan)

- Optional Requirements
  - Alkalies
  - Drying Shrinkage
  - Multiple Factor
  - Uniformity

Fly Ash

- Non-Reactive Aggregates
  - 15 – 35% of Total Cementitious (Mass)
- Reactive Aggregate (ASR Mitigation):
  - Class F:
  - 25 - 40 % of Total Cementitious (Mass)
  - Calcium Oxide (CaO): < 8%

Ground Granulated Blast Furnace Slag
GGBF



- ASTM C 898
  - Grade 120
  - 40% - 50% of Total Cementitious (Mass)
- Technical Support Available

Cement Certification and Mill Test Reports

January 23, 2001

A. S. Horner, Inc.
dba AKAMAI Enterprises, Inc.
P.O Box 9105
Albuquerque, NM 87119

COMPLIANCE AFFIDAVIT

Portland Cement, Type I-II LA, as manufactured by CEMENTOS DE CHIHUAHUA SA DE CV, at Samalayuca, Mexico is warranted to conform at the time of shipment to current ASTM Specification C-150.

No other warranty is made or to be implied.

Sincerely,

Rick Percival
Market Manager

Sales Office
4253 Montgomery NE, Suite 210
Albuquerque, NM 87109
(505) 881-5303
1-800-234-2266
Fax 881-5304

A compan

RIO GRANDE PORTLAND CEMENT CORP.
Manufacturing Plant:
Samalayuca, Chih, Mexico

Mailing Address:
4253 Montgomery Blvd.N.E.
Suite 210
Albuquerque, New Mex 87109
(505) 881-5303
FAX (505) 881-5304

Car Numbers:
CEFX 80197 CEFX 80038 CEFX 80066 CEFX 80191

Report No.:	1619
Date Shipped:	AGO 2 Th
Mfg. Plant:	SAMALAYUC
Cement Type:	I - II Low Al
Quantity:	4 RAIL CAR
Shipping No.:	1682

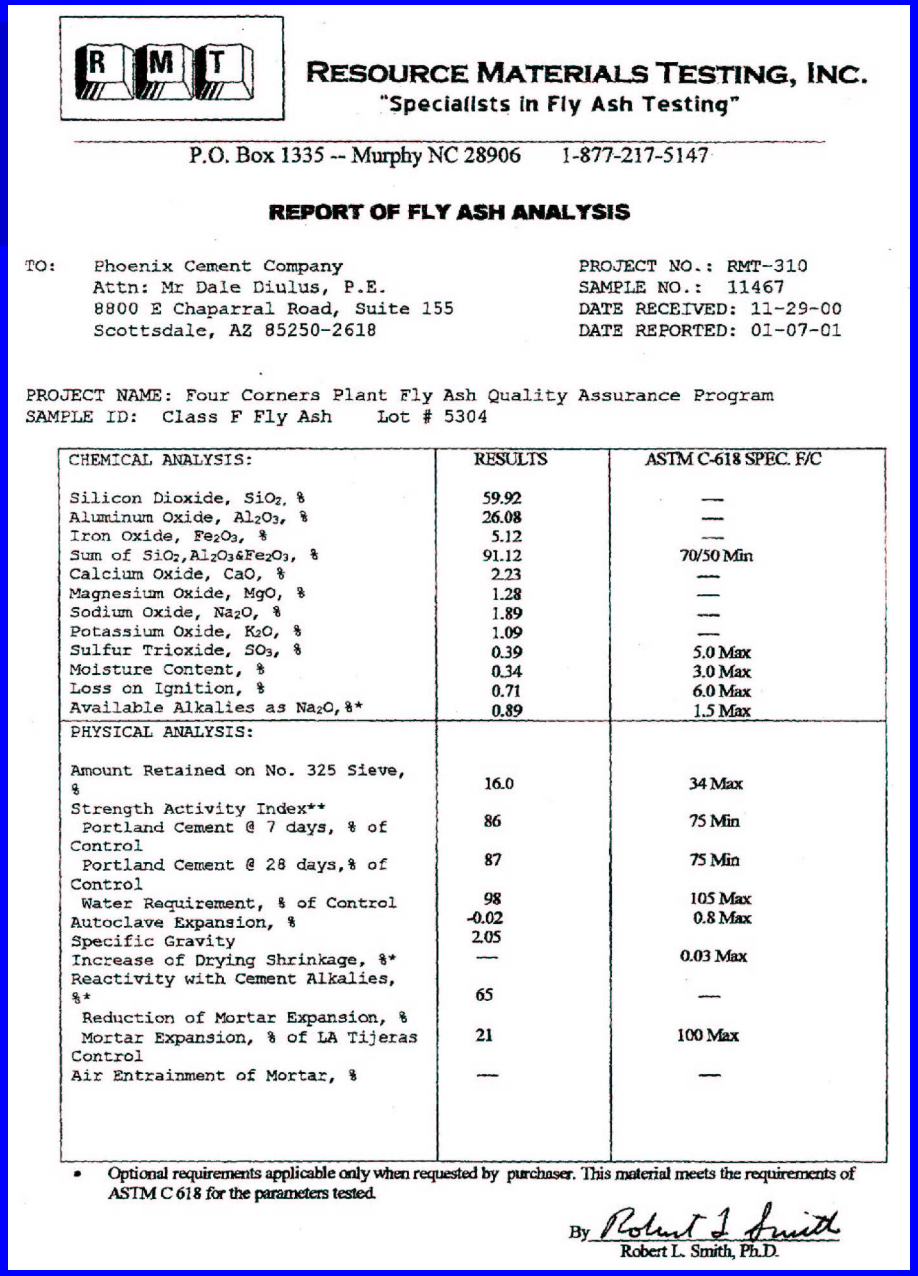
STANDARD CHEMICAL REQUIREMENT:	SPECIFICATIONS ASTM	II	TEST RESULT
Silicon Dioxide (SiO2) - Percent	Minimum >	20.0	21.2
Aluminum Oxide (Al2O3) - Percent	Maximum >	6.0	4.7
Ferric Oxide (Fe2O3) - Percent	Maximum >	6.0	3.2
Calcium Oxide (CaO) - Percent		*	63.8
Magnesium Oxide (MgO) - Percent	Maximum >	6.0	2.0
Sulfur Trioxide (SO3)- Percent	Maximum >	3.0	2.8
Loss on Ignition - Percent	Maximum >	3.0	1.48
Insoluble Residue - Percent	Maximum >	0.75	0.32
Tricalcium Silicate (C3S) - Percent		*	54
Dicalcium Silicate (C2S) - Percent		*	20
Tricalcium Aluminate (C3A) - Percent	Maximum >	8	7
Tetracalcium Aluminoferrite (C4AF) - Percent		*	10
C4AF + 2 (C3A) or C4AF + C2F - Percent		*	24
Alkalies (Sodium Oxide Equivalent) - Percent *	Maximum >	0.60	0.57
STANDARD PHYSICAL REQUIREMENTS			
Specific Surface , Wagner ,m2/kg	Minimum >	160	200
Specific Surface , Blaine ,m2/kg	Minimum >	280	349
- 325 Mesh - Percent		*	90.4
Compressive Strengths,psi (MPa)(C 109 cubes)			
psi (MPa)		psi (Mpa)	
1 DAY		*	1695 (
3 DAYS	Minimum >	1500 (10.3)	3200 (
7 DAYS	Minimum >	2500 (17.2)	4140 (
28 DAYS	Minimum >	*	
Time of Setting (Vicat)			
Initial ,minutes	Minimum >	45	101
Final ,minutes	Maximum >	375	195
False Set - Percent *	Minimum >	50	93
Air Content of Mortar - Percent	Maximum >	12	6.8
Autoclave Expansion - Percent	Maximum >	0.80	0.01
Mortar Bar Expansion (ASTM C -1038) - Percent	Maximum >		

* Optional (Sodium Oxide Equivalent) 0.54 MAX. 0.57

RIO GRANDE PORTLAND CEMENT IS WARRANTED TO CONFORM AT THE TIME OF SHIPMENT WITH ASTM C -150 NO OTHER WARRANTY IS MADE OR IMPLIED. HAVING NO CONTROL OVER THE USE OF IT'S CEMENTS , RIO GRANDE PORTLAND DOES NOT GUARANTEE FINISHED WORK.

SAMALAYUCA PLANT - TECHNICAL MANAGER

Fly Ash Certification and Mill Test Reports



RESOURCE MATERIALS TESTING, INC.
"Specialists in Fly Ash Testing"

P.O. Box 1335 -- Murphy NC 28906 1-877-217-5147

REPORT OF FLY ASH ANALYSIS

TO: Phoenix Cement Company
Attn: Mr Dale Diulus, P.E.
8800 E Chaparral Road, Suite 155
Scottsdale, AZ 85250-2618

PROJECT NO.: RMT-310
SAMPLE NO.: 11467
DATE RECEIVED: 11-29-00
DATE REPORTED: 01-07-01

PROJECT NAME: Four Corners Plant Fly Ash Quality Assurance Program
SAMPLE ID: Class F Fly Ash Lot # 5304

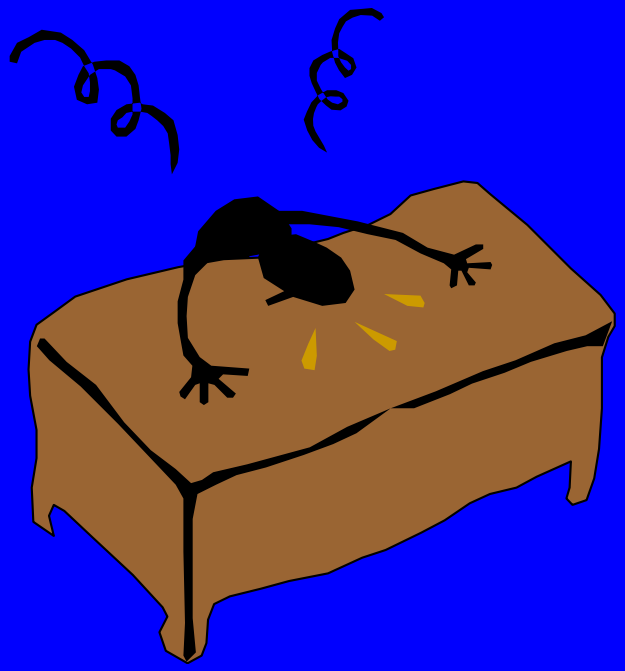
CHEMICAL ANALYSIS:	RESULTS	ASTM C-618 SPEC. F/C
Silicon Dioxide, SiO_2, %	59.92	—
Aluminum Oxide, Al_2O_3, %	26.08	—
Iron Oxide, Fe_2O_3, %	5.12	—
Sum of SiO_2, Al_2O_3 & Fe_2O_3, %	91.12	70/50 Min
Calcium Oxide, CaO, %	2.23	—
Magnesium Oxide, MgO, %	1.28	—
Sodium Oxide, Na_2O, %	1.89	—
Potassium Oxide, K_2O, %	1.09	—
Sulfur Trioxide, SO_3, %	0.39	5.0 Max
Moisture Content, %	0.34	3.0 Max
Loss on Ignition, %	0.71	6.0 Max
Available Alkalies as Na_2O, %*	0.89	1.5 Max
PHYSICAL ANALYSIS:		
Amount Retained on No. 325 Sieve, %	16.0	34 Max
Strength Activity Index**		
Portland Cement @ 7 days, % of Control	86	75 Min
Portland Cement @ 28 days, % of Control	87	75 Min
Water Requirement, % of Control	98	105 Max
Autoclave Expansion, %	-0.02	0.8 Max
Specific Gravity	2.05	
Increase of Drying Shrinkage, %*	—	0.03 Max
Reactivity with Cement Alkalies, %*	65	—
Reduction of Mortar Expansion, %		
Mortar Expansion, % of LA Tijeras Control	21	100 Max
Air Entrainment of Mortar, %	—	—

- Optional requirements applicable only when requested by purchaser. This material meets the requirements of ASTM C 618 for the parameters tested.

By Robert L. Smith
Robert L. Smith, Ph.D.

PAVEMENT DISTRESSES

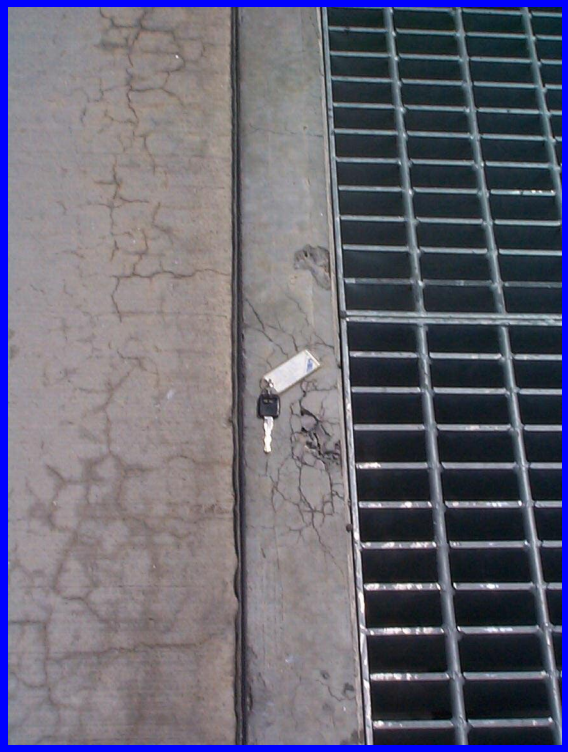
MATERIALS RELATED



ASR PAVEMENT DISTRESSES

KIRTLAND AFB, NM

ASR MAP CRACKING



HOLLOMAN AFB, NM

ASR Expansion Foundation Damage

Ft. Cambell, KY.

(Pavement)

(Structures)

“POP-OUTS”

Aggregates

Aggregates

- Comprise Largest Volume of Concrete Mixtures, Typically 60 -80%

- Grading, Size, Chemical Composition, Porosity, Surface Texture, and Shape Greatly Influence Plastic and Hardened Properties

- Must be Durable

Aggregates

- Satisfactory Service Record
  - Minimum 5 Years
  - Three Paving Projects
  - New Source
    - Freeze Thaw Testing
  - Performed By Qualified P.E.

Satisfactory Service Record

- Guidance ETL 1110-3-488:

  "Design and Construction Management Practices for Concrete Pavements"

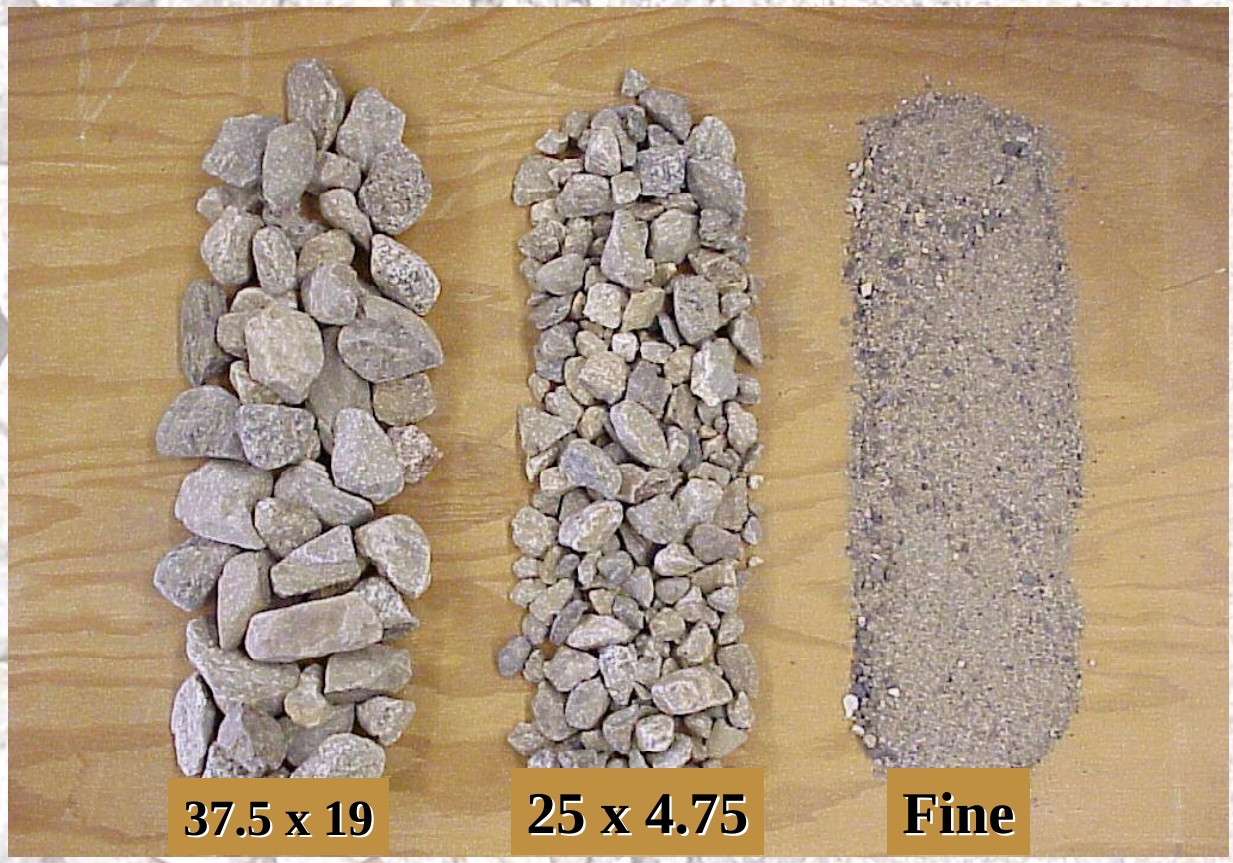
  - Material Sources
  - Material Quality
  - Mix Design
  - Design Parameters
  - Strength
  - Strength Tests
  - Pavement Condition
  - Distresses

Aggregates

- Aggregate Supplier
  - Quality Tests (Current within 1 Yr)
  - Internal Control Testing
    - Grading
    - Specific Gravity
- State Dot Quality Testing Program

Aggregates

Primary Aggregate Nominal Size



Coarse Aggregates

- ASTM C 33
  - Size 4 (19 mm - 37.5 mm)(3/4”/1-1/2”)
  - Size 67 (4.75 mm – 19 mm)(No. 4- / ¾”)
  - Crushed Stone
  - Washed, Clean, Hard, Uncoated

Coarse Aggregates

- Larger Coarse Aggregate Sizes
  - Occupies More Total Volume
  - Reduces Paste Content
  - Reduces Shrinkage
  - Reduces Water Demand
  - More Economical

Aggregates

- Calibration Hardstands
  - Free of Materials W/ Magnetic Properties
- Power Check Pads
  - Limestone, Dolomite, Basalt
  - Non-Thermal Sensitive Material
    - Distress From Jet Blast

Coarse Aggregate Quality

- Particle Shape
  - Spherical
  - Cubical
- Flat and Elongated Pieces
  - < 20% by Weight (Any Size)
  - Flat : W/T > 3
  - Elongated: L/W > 3

Flat and Elongated Pieces

Coarse Aggregates

- Flat and Elongated Pieces Test

  - Avoid Introducing Structural Planes of Weakness in Finished Concrete

  - Workability Problems w/ Excess F/E Pieces

  - Durability Problems if Air and Water Trapped Under F/E

Coarse Aggregate Quality

- Freeze / Thaw
  - CRD-C 114
    http://www.wes.army.mil/SL/MTC/handbook
  - Durability Factor (> 50)
- Los Angeles Abrasion (Wear Test)
ASTM C 131
  - < 40%

Fine Aggregate

- ASTM C 33 Grading
- Particle Shape
  - Cubical
  - Spherical
- Soundness
- Sand Equivalency

Fine Aggregate

- Composition
  - Clean, Hard & Durable
  - Manufactured / Natural / Combination
- Free of Clayballs and Wood

Fine Aggregate Quality

- Freeze / Thaw
  - Durability Factor (> 50)
  - CRD-C 114
- Fineness Modulus (CRD C 104)
  - FM > 2.50 and FM < 3.0

Alkali-Silica Reactivity (ASR)

Alkali-Silica Reactivity in Hardened Concrete

- Step 1 – Alkali + Silica React forming a Gel Reaction Product
- Step 2 – Gel Reaction Product Absorbs Moisture and Expands
- Expansion Causes Damage

ASR Test Methods

- C 295 - Petrographic Examination
- C 289 – Quick Chemical Test (False Negatives)
- C 227 – Mortar Bar Test (False Negatives)
- C 1260 – Accelerated Mortar Bar Test
- C 1293 – Concrete Prism Test (CPT)

C 295 - Petrographic Examination

- Known Reactive Rock Types
- Presence of Known Reactive Constituents

Reactive Constituents

- Cristobalite, Tridymite
- Volcanic Glass (SiO_2)
  - Felsic (+ 66%)
  - Intermediate (Less than 52%)

- Opal
- Chalcedony
- Quartz
  - Granulated, Strained, Microcrystalline, Cryptocrystalline

ASTM C-1260 Test

ASTM C 1260

- Test Fixed Grading (No 4 - No. 100)
- W/C Ratio: 0.47
- Fabricate Mortar Bars: 1”x1”x11.2”
- Use Project Cement and Mitigation Agent
- Data in 16 days

ASTM C 1260 - ASR Testing

- Test Individual Aggregates (Coarse and Fine)
- Test Proposed Aggregate Blend (Proposed Mix)
- Length Change Determined at Least 3 times Over a 14 day Period

ASTM C 1260 Specimens Albuquerque, NM Aggregates

- Approved Laboratory
- Vary Quantity of Mitigating Measure During Testing

All Aggregates

- Alkali-Silica Reactivity
- Test each Aggregate Size
- ASTM C-1260 (Modified)
  - Proposed Aggregate Blend (i.e. 60/40)
  - Utilize Project Materials
    - Cement
    - Class F Fly Ash (25 - 40% by Mass)

All Aggregates

- Alkali-Silica Reactivity
  - ASTM C-1260 (Modified)
  - Proposed Blend: Expansion less than 0.08 @ 16 Days.
  - If Test Fails – Reject Aggregate Contractor shall Submit New Source

Texts on ASR Basics

- ACI 221.1-98 – State-of-the-Art Report on Alkali-Aggregate Reactivity
- SHRP C-315 – Handbook for the Identification of ASR in Highway Structures
  http://leadstates.tamu.edu/asr/library/C315
- PCA – Diagnosis and Control of AAR in Concrete (ACPA, NSSGA, NRMCA)

ASR Technical Report

NAVAL FACILITIES ENGINEERING SERVICE CENTER
Port Hueneme, California 93043-4370

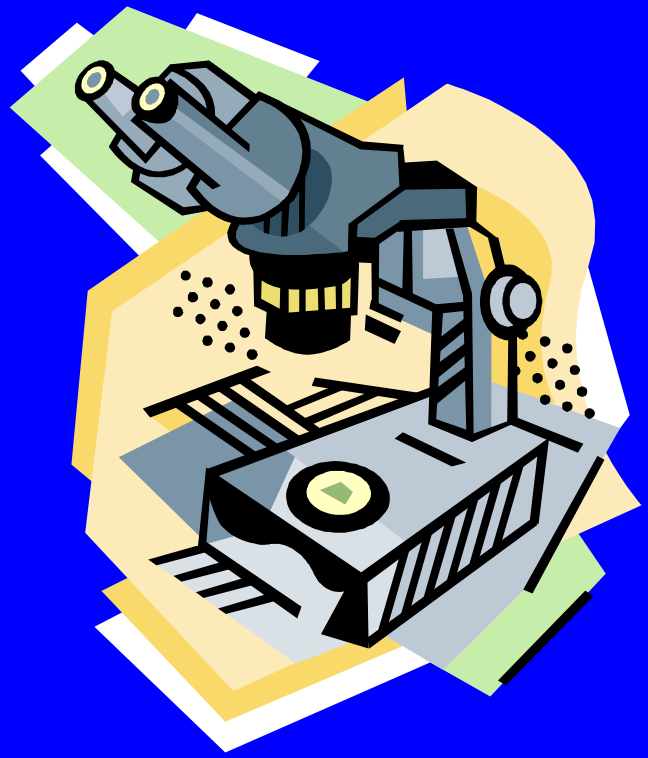
Technical Report
TR-2195-SHR

ALKALI-SILICA REACTION MITIGATION STATE-OF-THE-ART

by L.J. Malvar, NFESC

and Team Members

PETROGRAPHY



Petrographic Identification

- Describes and Classify Aggregate Constituents
- Determines Relative Amounts of Constituents
- Identification of Unstable Materials
    - (Chemical, Thermal, Moisture)
- Quantifies Weathered/ Altered Particles in Coarse Aggregates

Petrographic Identification

- Evaluate Shape, Angularity, & Surface Texture

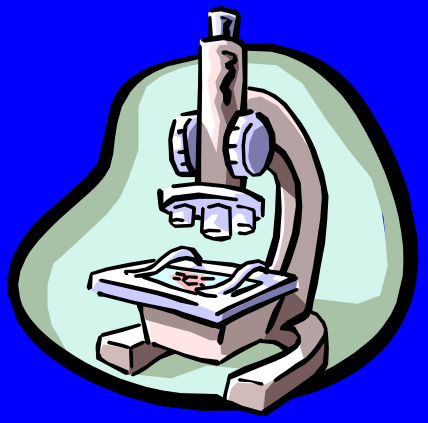
- Identify Presence Of Alkali- Reactive Constituents

- Identify Contaminants (Gypsum, Soil,Etc)

Petrographic Identification

- General Visual Examination
  - Unaided Eye, Hand Lens, Stereomicroscope
- Detailed Mineralogic Profile
  - Polarizing Microscope
    - Thin Sections
  - X-ray Diffraction (XRD)

Petrographic Identification Requirements



- USACE Approved Lab
- Petrographic Examiner
  - Furnish Resume to USACE
  - Subject to Approval 10 Days Prior to Testing
- ASTM C-295
- Follow Detailed Specification Procedure

Petrographic Requirements

- No Additional Time, Payment Due To Delays In Testing, Evaluation Or Personnel Requirements

- Material Quantity

  - Coarse (¾” To 1 ½”): 200 Lbs. (90 Kg)
  - Coarse (No. 4 To ¾”): 25 Lbs. (12 Kg)
  - Fine: 10 Lbs. (5 Kg)

Deleterious Materials

COARSE AGGREGATES

- Clay Lumps and Friable Particles	0.2 Max.
- Shale	0.1 Max.
- Material Finer Than 0.075 mm (No. 200)	0.5 Max.
- Lightweight Particles (2.0 Sp.G)	0.2 Max.
- Clay Ironstone	0.1 Max.
- Chert and Cherty Stone (<2.4 Sp.G)	0.1 Max.
- Claystone, Mudstone, Siltstone	0.1 Max.
- Shaly and Argillaceous Limestone	0.2 Max.
- Other Soft Particles	1.0 Max.
- Total of All Deleterious Materials Except Material Finer Than 0.075mm	1.0 Max.

Deleterious Materials

FINE AGGREGATE

- Clay Lumps and Friable Particles	1.0 Max.
- Material Finer Than 0.075 mm (No. 200)	3.0 Max.
- Lightweight Particles (Medium Sp. G = 2.0)	0.5 Max.
- Total of All Deleterious Materials	3.0 Max.

Deleterious Testing Recurring Issues

- Submission of Outdated Information or ASTM C 295 Evaluation. (Smaller Samples). Evaluation Does Not Address Table of Deleterious Materials Noted In UFGS.

- Submission of Test Data Performed by Non-Validated / Accredited Laboratories and /or Petrographer.

  - Only 4 Labs USACE Validated for ASTM C 295

  - CCRL and AMRL DO NOT Inspect Labs for ASTM C 295

- Lab/ Petrographer NOT Provided Copy of Spec or Testing Sequence Described in UFGS.

Deleterious Testing Recurring Issues

- Petrographic Examiner Unaware of Minimum Test Sample Sizes or Required Testing Sequence Noted In UFGS.

- Petrographic Examiner Not Utilizing Separation Medium of 2.40 Sp.G. in Determination of Chert and Cherty Stone.

- Insufficient Lead Time Given to Lab to Perform Testing. Deleterious Examination Report Should be Reviewed and Approved Prior to Starting Mix Design Studies.

- Ktr. Complaints of Associated Cost of Test and Length of Time To Obtain Test Evaluation Data.

- Assure Testing Is Performed and Not Waived. Repetitive Lack of Enforcement, of this Requirement, Exists.

Petrographic Report

and tuff. The latter three rock types are siliceous volcanic rocks that may contain reactive tridymite and cristobalite. Minor constituents of the samples include chert, fresh and weathered sandstone, schist, and gneiss. Traces of siltstone are present in the Intermediate Aggregate.

Aggregate particles are angular to subrounded and blocky to oblong. Tabular rock chips are common in the 3/8-in. and No. 4 sieve fractions. Surfaces are smooth to hackly and predominantly firm. Thin partial coatings of white calcareous caliche are tightly adhered to a small number of particles (estimated 1 to 2%).

TABLE 1 DELETERIOUS MATERIALS IN AGGREGATE SAMPLE (% BY MASS)

Materials	Limit	Coarse Aggregate	Intermediate Aggregate
Material finer than 0.075 mm ASTM C 117	1.0	0.3	0.2
Clay lumps and friable particles ASTM C 142	2.0	1.2	0.6
Lightweight particles <2.00 Specific Gravity ASTM C 123	0.5	0.012	0.008
Chert and cherty stone <2.40 Specific Gravity (ASTM C 123, C 295)	5.0	2.84	1.36
Shale ASTM C 295	1.0	0	0
Shale and argillaceous limestone ASTM C 295	1.0	0	0
Claystone, mudstone, and siltstone ASTM C 295	1.0	0	0.04
Clay ironstone ASTM C 295	1.0	0	0
Other soft particles COE CRD-C 130	2.0	0.88	1.29
Total of all deleterious materials exclusive of material finer than 0.075 mm	5.0	4.93	3.30

METHODS

Testing was carried out in accordance with the sequence of testing requirements of 2.2.2.6 of Section 02753A Unified Facilities Guide Specifications, Concrete Pavement for Airfields and Other Heavy-Duty Pavements.

Sample mass was 11,342 grams for No. 57 aggregate, and 4,539.5 grams for No. 8 aggregate. ASTM procedures for C 117, C 142, and C 123 were followed except that sample mass requirements of the COE specifications were used.

For C 295 petrographic examination, the aggregate samples were thoroughly cleaned and dried after testing for C 123 testing for lightweight materials, and then sieved according to ASTM C 136, "Standard Method for Sieve Analysis of Coarse and Fine Aggregate." Particles were studied in accordance with ASTM C 295-98, "Standard Practice for Petrographic Examination of Aggregates for Concrete." All particles in each sieve fraction were examined. One fifth of each sample (by mass) was then tested for scratch hardness in accordance with COE CRD-C 130.

Laura J. Powers
Principal Microscopist
Microscopy Group

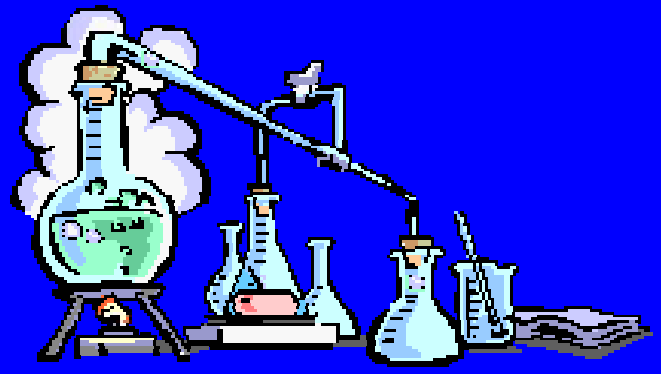
LJP/ljp

154795

Attachments

I:\WP\000\154795 New West

Chemical Admixtures



ADMIXTURES

- Used to Modify Concrete Properties
  - Improve Workability
  - Reduce Quantity of Mixing Water
  - Control Initial Set

Admixtures

- Reduce Heat Generation
- Accelerate Strength Gain
- Increase Strength
- Improve Durability

Chemical Admixtures

- Air Entraining (ASTM C 260)

- Water-Reducer (ASTM C 494; Type A or D)

  - Six Month / One Year Strength Tests Waived

Chemical Admixtures

- Retarder (ASTM C 494; Type B)
  - Shall Not Be Used To Decrease Cementitious Content
- Accelerator (ASTM C 494; Type C)
  - Calcium Chloride Not Permitted

Chemical Admixtures

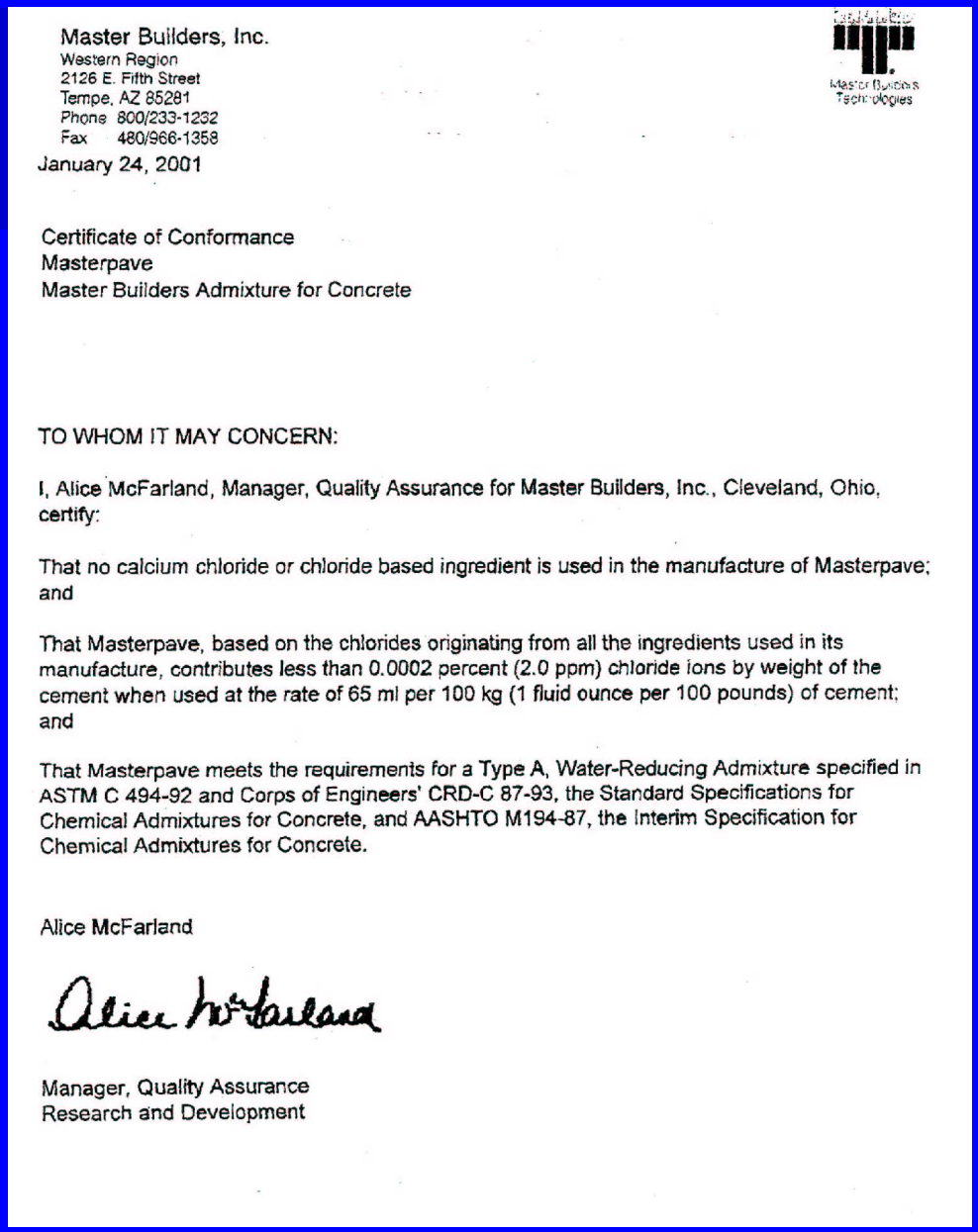
- Only Admixtures Used in Approved Mix Design
- Dosage per Design Requirements
- No Substitution, Deletion, Interchanging of Admixtures Permitted W/O Verification Testing

Chemical Admixtures

- Certificates of Compliance
- Manufacturer Test Reports
- High Range Water Reducing Admixtures NOT permitted
- Technical Support Available

Cement Certification and Mill Test Reports

- Identification of Lot
- Current Certification



Master Builders, Inc.
Western Region
2126 E. Fifth Street
Tempe, AZ 85281
Phone 800/233-1232
Fax 480/966-1358

January 24, 2001

Certificate of Conformance
Masterpave
Master Builders Admixture for Concrete

TO WHOM IT MAY CONCERN:

I, Alice McFarland, Manager, Quality Assurance for Master Builders, Inc., Cleveland, Ohio, certify:

That no calcium chloride or chloride based ingredient is used in the manufacture of Masterpave; and

That Masterpave, based on the chlorides originating from all the ingredients used in its manufacture, contributes less than 0.0002 percent (2.0 ppm) chloride ions by weight of the cement when used at the rate of 65 ml per 100 kg (1 fluid ounce per 100 pounds) of cement; and

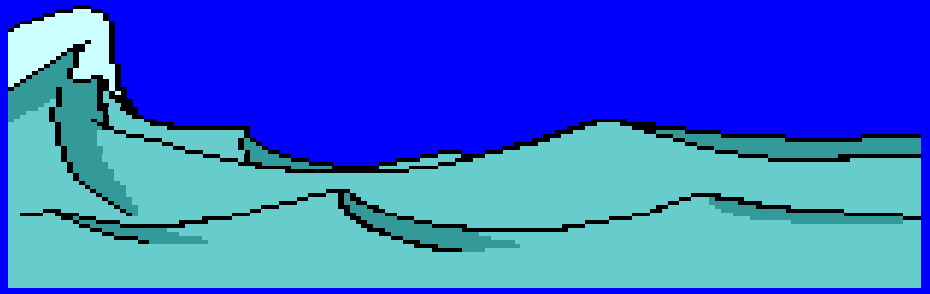
That Masterpave meets the requirements for a Type A, Water-Reducing Admixture specified in ASTM C 494-92 and Corps of Engineers' CRD-C 87-93, the Standard Specifications for Chemical Admixtures for Concrete, and AASHTO M194-87, the Interim Specification for Chemical Admixtures for Concrete.

Alice McFarland

Alice McFarland

Manager, Quality Assurance
Research and Development

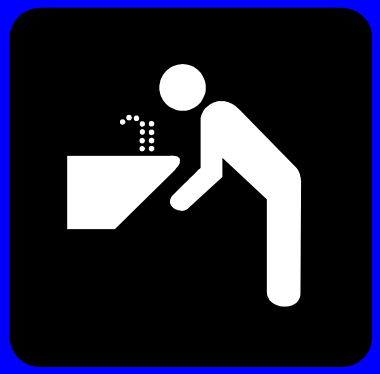
Water



Water

- Fresh - Clean
- Potable
- Minimal Amounts
  - Oil - Acid
  - Salt - Alkali
- Non -Potable
- CDR-C 400

WATER



- Chorides (Cl) 1000 ppm Max.
- Sulfates (SO_4) 3000 ppm Max.
- Alkalis (NaO) 600 ppm Max.
- Total Solids 50,000 ppm Max.

ASTM C 94

US Army Corps of Engineers®
South Pacific Division

Albuquerque District

Concrete Mix Design Requirements

Presented by: Gene Gutierrez

gene.gutierrez @usace.army.mil 505.342.3485

Mix Design

- Determine the Most Economical and Practical Combination of Materials to Produce a Concrete That Satisfies the Specification and Performance Requirements

- Strength and Durability

- Consistency and Uniformity

- Acceptable Workability

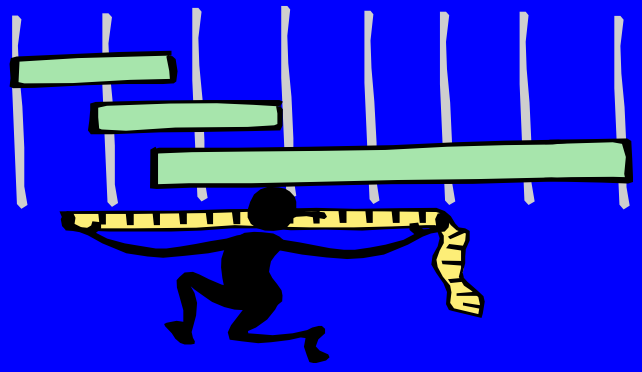
Laboratory Mix Design Guidelines

- Develop mixes with different w/cm ratios to establish sensitivity of flexural strength with w/cm ratio (establish a 3 point curve)
- Monitor slump loss during mix design. Excessive slump loss (1 in. in 15 minutes) may indicate false setting or material incompatibility problem
- Conduct early age strength tests to evaluate potential problems at 28 days
- Monitor concrete cylinder temperature during first 12 hours. Only a small temperature increase may indicate retardation tendency due to material incompatibility

Best Practices Manual

Mix Design Requirements

- COE Validated / Approved Laboratory
- ACI – 211 Methodology
- Representative Materials with Test Reports / Certifications



Mix Design Requirements

- Cementitious Material Approval
- Proportion Aggregates at SSD
- No Substitutions of Materials Permitted Without Additional Testing and Approval

Aggregate Gradation

- Determine Optimum Overall Gradation of Coarse and Fine Aggregates
- Workability
- Minimize Paste Content
- Blend to meet “AF Gradation Requirements”
  - Dense Grading

Air Force Gradation Requirements

- Mandatory on all USAF Projects

- Method for Selecting Aggregate Grading for Use in Concrete Mixes

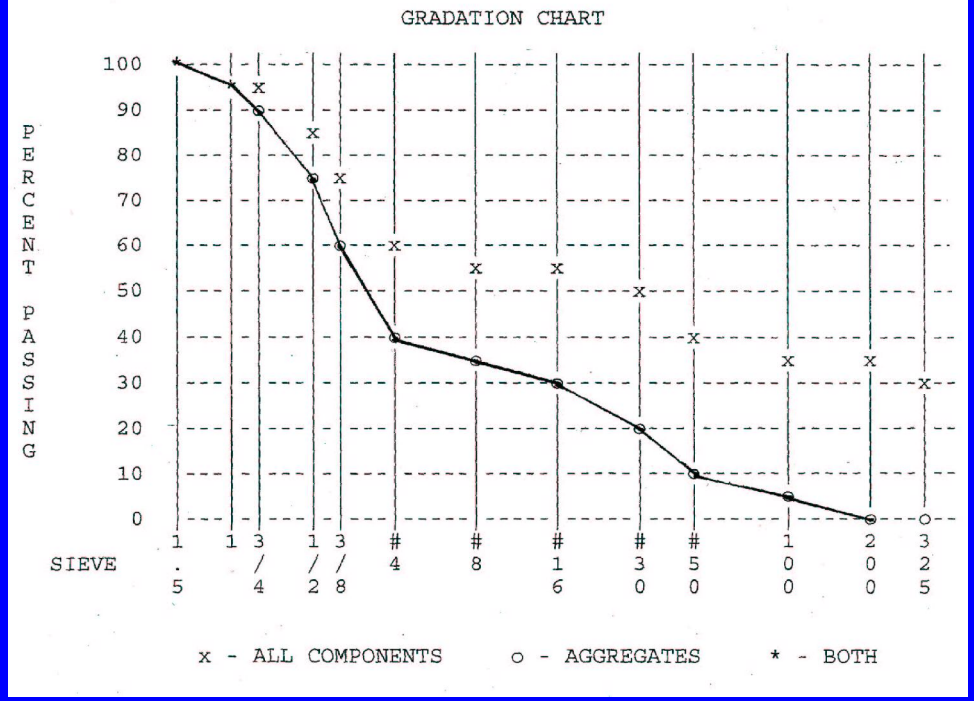
- Treats the Combined Aggregate Grading as a Single Component Instead of Individual Size Gradings

Combined Aggregate Grading

SIEVE SIZE	PERCENT PASSING N0. 4	NO. 67	SAND	AGG 4	AGGREGATE BLENDED TOTAL BY WEIGHT	VOLUME aggregate
1.5	100.0	100.0	100.0	0.0	100.0	100.0
1.0	51.0	100.0	100.0	0.0	94.7	94.8
3/4	8.0	97.0	100.0	0.0	88.9	89.1
1/2	3.0	56.0	100.0	0.0	71.8	72.0
3/8	2.0	30.0	100.0	0.0	61.1	61.4
#4	2.0	4.6	89.0	0.0	45.5	45.7
#8	2.0	3.0	71.0	0.0	36.1	36.3
#16	0.0	0.0	67.0	0.0	32.7	32.9
#30	0.0	0.0	43.0	0.0	21.0	21.1
#50	0.0	0.0	18.0	0.0	8.8	8.8
#100	0.0	0.0	4.0	0.0	2.0	2.0
#200	1.1	2.0	1.8	0.0	1.8	1.8
#325	0.0	0.0	0.0	0.0	0.0	0.0
PAN	0.0	0.0	0.0	0.0	0.0	0.0
FM	7.85	6.63	3.06	9.00	5.02	5.01

Combined Gradation

SIEVE	STONE 1	STONE 2	STONE 3	SAND	PASTE	TOTAL	AGGR
1-1/2 "	100.0					100.0	100.
1 "	43.0					96.0	94.
3/4 "	8.0	100.0				93.5	90.
1/2 "	3.0	64.0	100.0			82.8	74.
3/8 "	3.0	31.0	94.0	100.0		72.9	59.
# 4	2.0	4.0	17.0	97.0		59.7	40.
# 8	2.0	3.0	5.0	85.0		55.7	34.
# 16	2.0	2.0	3.0	78.0		53.5	30.
# 30	2.0	1.0	2.0	57.0		47.8	22.
# 50	1.0	1.0	2.0	26.0		39.9	10.
# 100	1.0	1.0	2.0	9.0		35.6	4.
# 200	0.9	0.9	1.7	2.0	100.0	33.8	1.
# 325	-	-	-	-	95.3	31.3	-
Liquid	-	-	-	-	61.0	20.0	-



Coarseness and Workability Factors

Coarseness Factor (CF):

(Cumulative % Retained 9.5mm(3/8") Sieve / Cumulative % Retained 2.36mm(No. 8 Sieve)) X 100

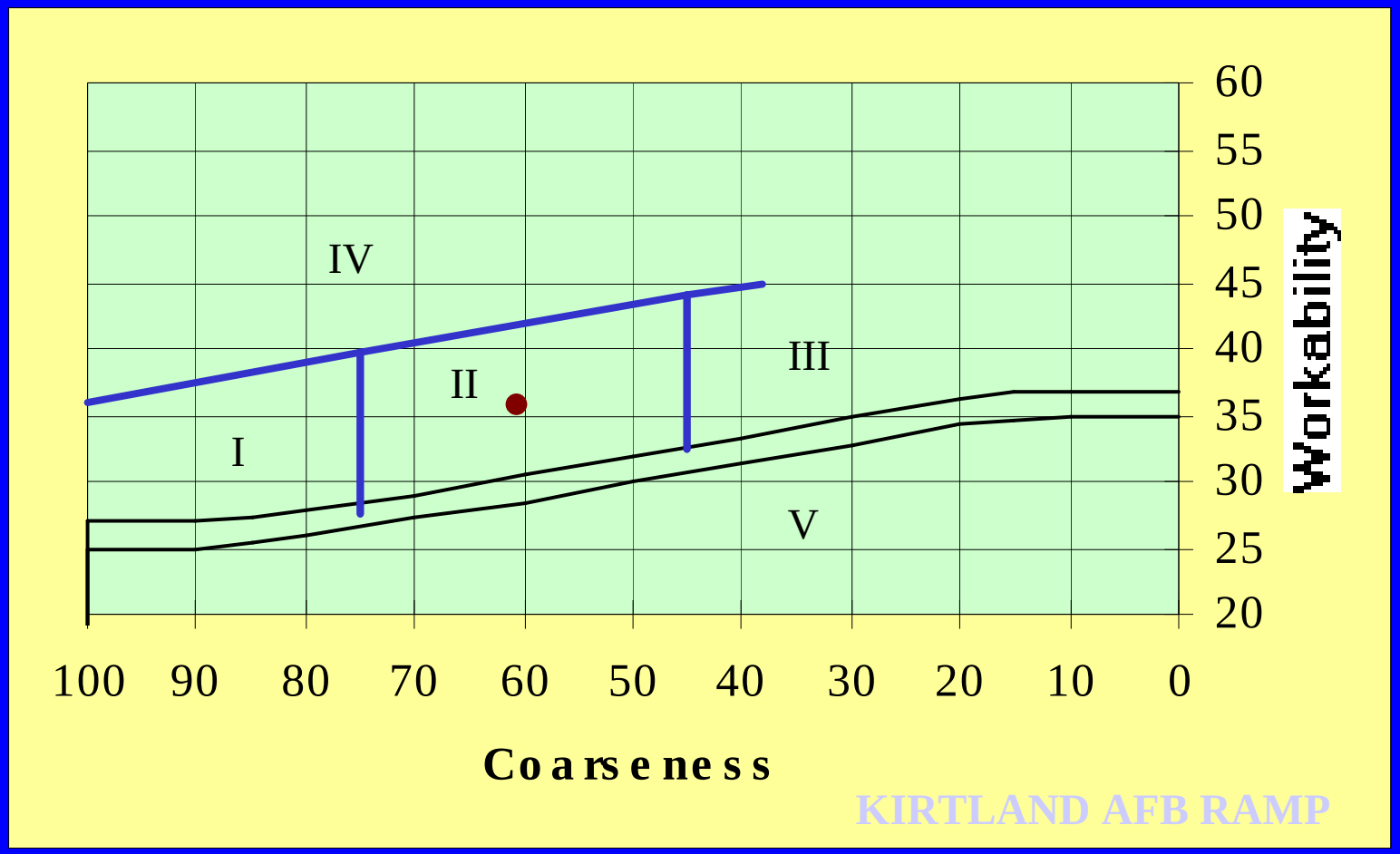
Workability Factor (WF):

Cumulative % Passing 2.36mm (No. 8) Sieve

- Adjust Upwards Only 2.5% Per 42KG (94 Lbs.) Cementitious

Greater Than 335 KG (564 Lbs.)

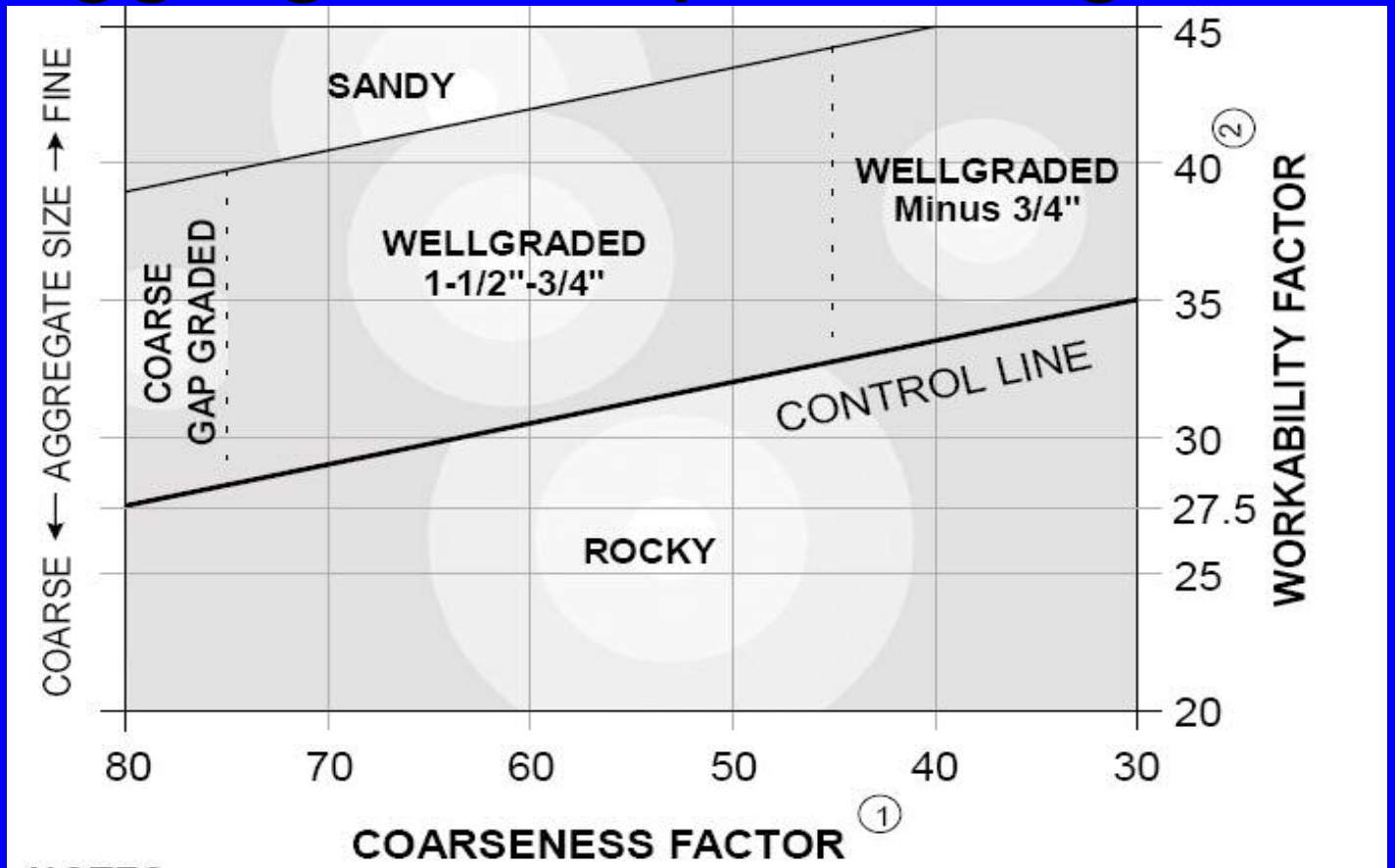
Coarseness and Workability Factor



ZONE DESCRIPTIONS

Zone I - Coarse, Gap-Graded Tends to Segregate
Zone II - Well graded 1-1/2" and 1"
Zone III- 3/4" and Finer
Zone IV- Sticky
Zone V - Rocky

Aggregate Proportioning Guide

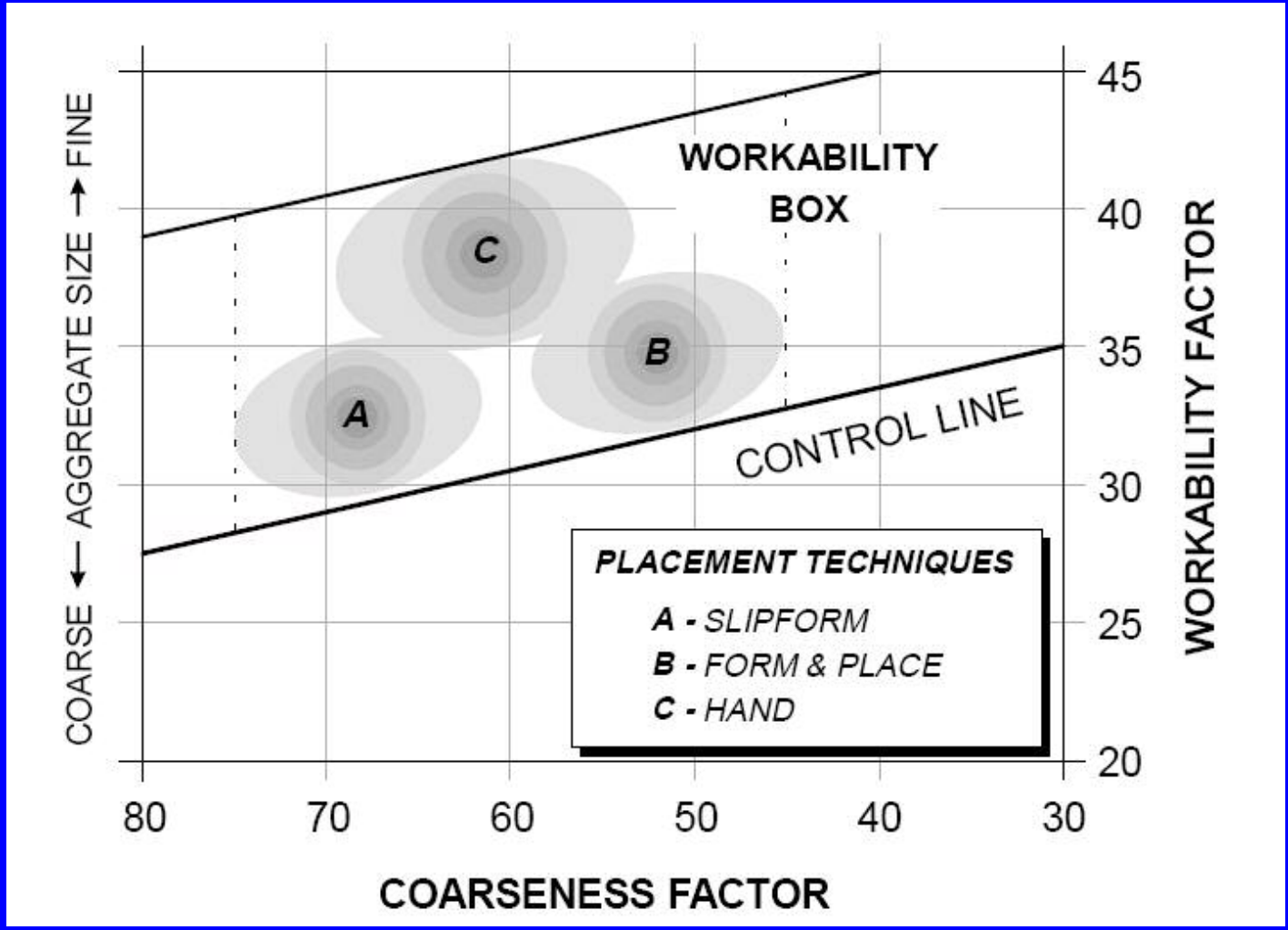


NOTES:

① **COARSENESS FACTOR =** $\dfrac{\text{\% RETAINED ABOVE 9.5mm SIEVE}}{\text{\% RETAINED ABOVE \#8 SIEVE}}$ X 100

② **WORKABILITY FACTOR =** % PASSING #8

Workability Box Within Aggregate Proportioning Guide



USAF ETL 97-5

“Hay Stack” Curve

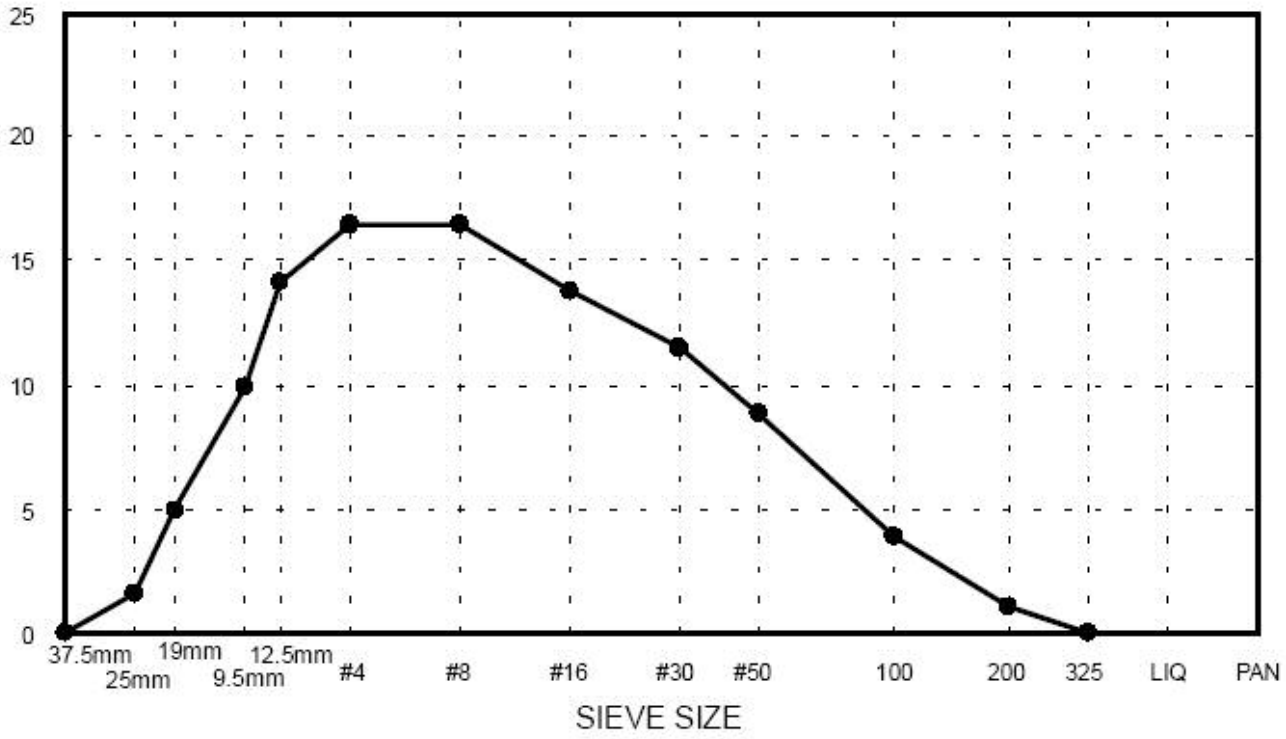
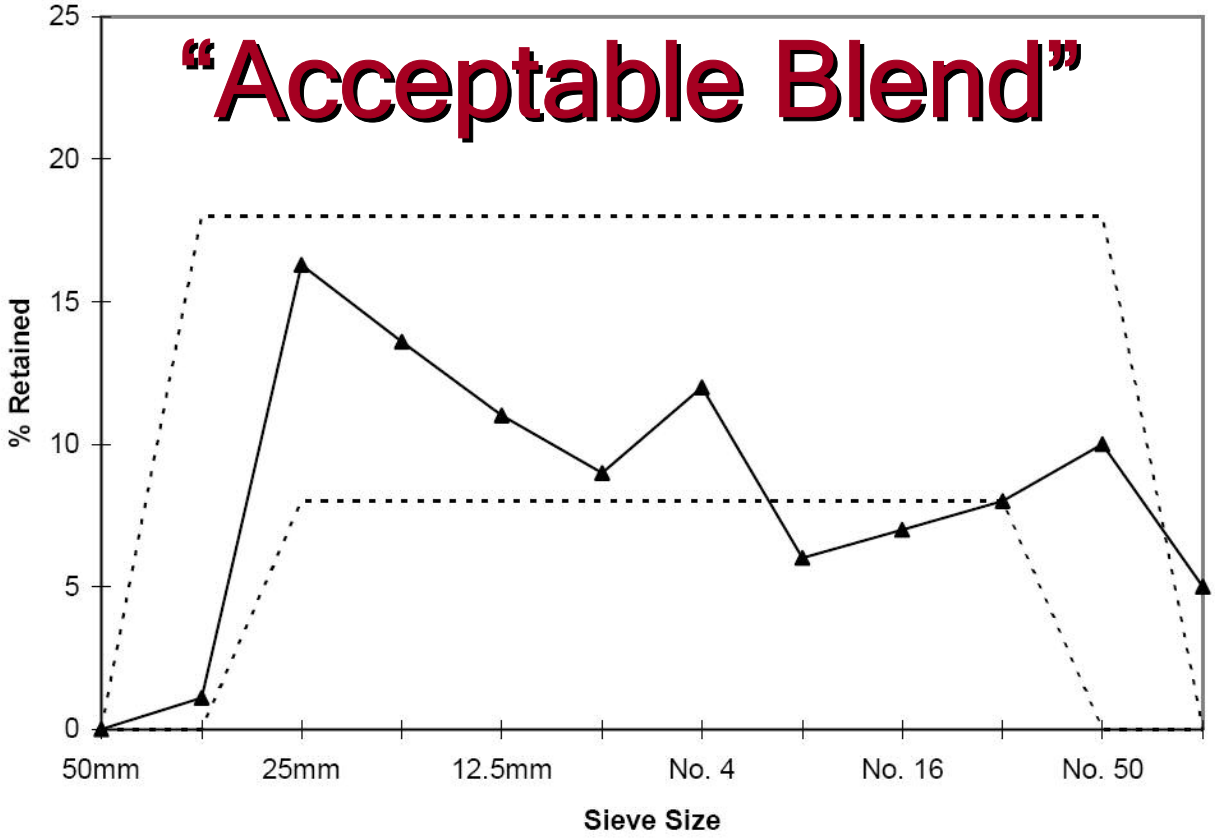


Figure 3.5 “Haystack” Particle Distribution for a Uniformly Graded Mixture

“In a Perfect World”

"Acceptable Blend"

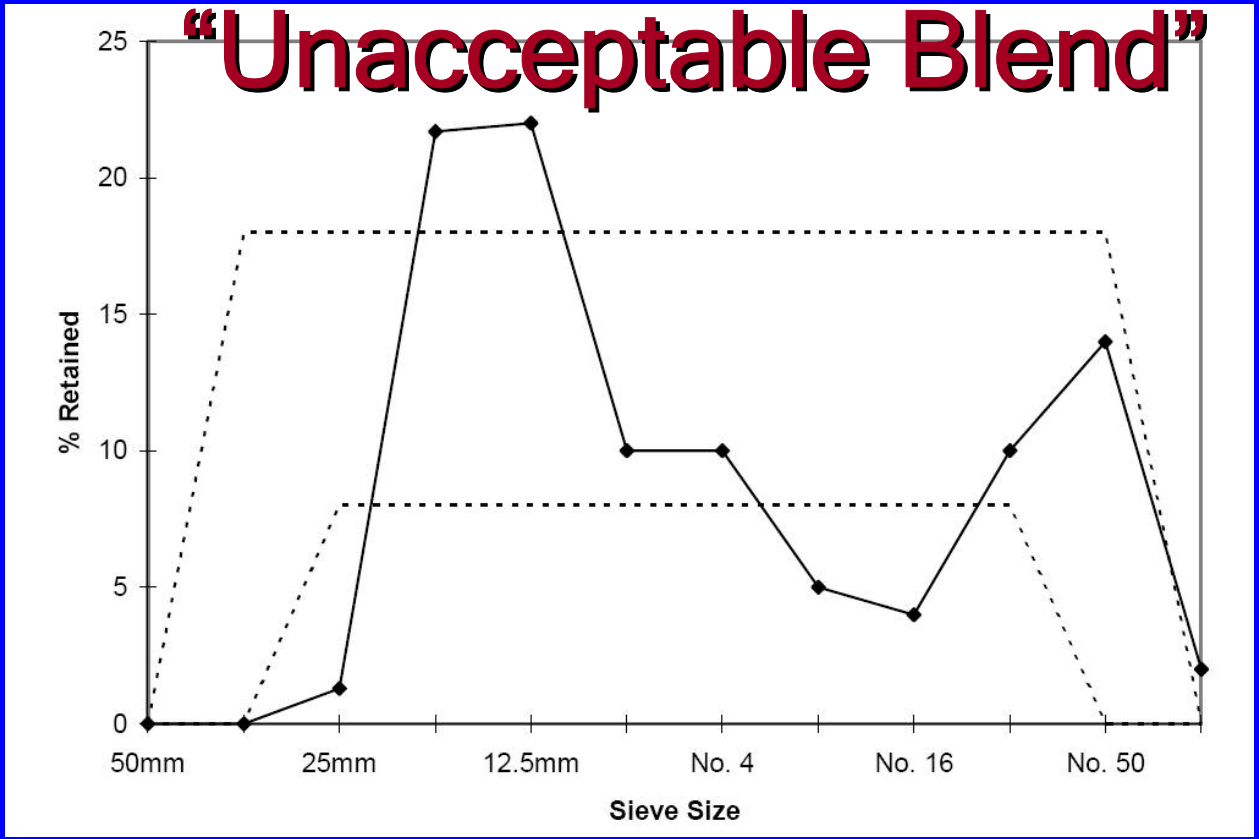


A general rule of thumb is to keep the material retained on each sieve to less than 18 percent but more than 8 percent.

An acceptable curve will have peaks prior to the 9.5mm size and then a uniform transition to the lowest size materials. In this Example, the small peak at the No. 4 sieve size would be acceptable since the valley following the No. 4 is about the same percentage from the deviation of a straight line between the 9.5mm size and the No. 16 sieve size.

USAF ETL 97-5

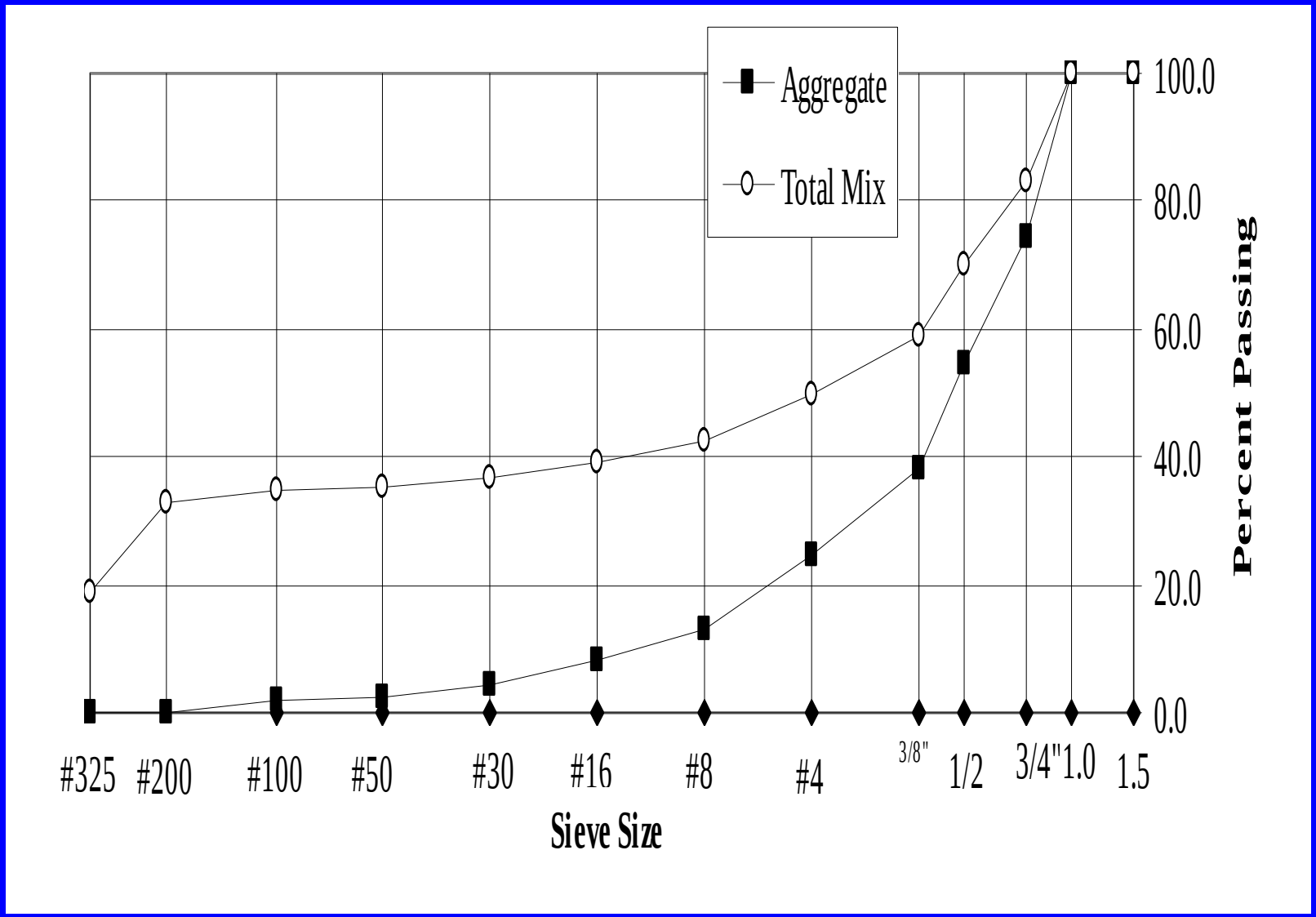
"Unacceptable Blend"



For this material, the peak in the curve occurs at and adjacent to the top size of the aggregate; i.e., the first sieve size which retains material. The adjacent sieve size is also at the peak. The result is that there is a large quantity, by weight, of large stone sizes. There is little volume left to provide for the blend and the fine aggregate sizes. The resulting combined aggregate grading will have a "plums in the pudding" effect. These mixtures tend to segregate upon vibration and finish poorly because of excessive voids which must be filled with mortar.

USAF ETL 97-5

Gradation Curve - Total Blend



Mix Design Requirements

- Specified Flexural Strength: Based on Beams
  - 4. 83 Mpa (700 PSI) @ 90-days age
- Max. Allowable Water/Cement Ratio: 0.45
- Minimum Cementitious Content: 307 Kg/CM
- Fly Ash in Mixture
  - Minimum Cement Content: 335 Kg/CM

Mix Design Requirements

- Non-Reactive Aggregates
  - 15 – 35% of Total Cementitious (Mass)
- Reactive Aggregate (ASR Mitigation):
  - Class F:
  - 25 - 40 % of Total Cementitious (Mass)
  - Calcium Oxide (CaO): < 8%

Mix Design Requirements

- Air Content: 4.5% To 7.5% at Paver
- Maximum Slump
  - Slipform: Contractor Selects at Start of Project
  - Fixed Form: 50 Mm (2 Inches)
- Trial Batches (3 Different Water/Cement Ratios)

Mix Design Requirements

- Proportion Batches at
  - Maximum Allowable Slump
  - Maximum Allowable Air Content
- No HRWRA or Flowing Concrete Permitted
- No Changes to Design Dosages: WRA & RA

Mix Design Requirements

For Change in Materials: Conduct New Mix Design Studies

- No Paving Until COE Approval of Mix Design

Mix Design Requirements

Separate Trial Mixture Studies for

- Each Combination of Proposed Materials i.e. Cementitious, Admixtures

- Special Properties i.e. Type III, Trap Rock (Thermal Areas)

- Placement Methods i.e. Hand or Odd-Shaped Slabs, Placing/Finishing Equipment

Mix Design Testing

Strength Testing

- For Each Mixture (3 Different Water/Cement Ratios)

- Fabricate and Test Six Beams AND Six Cylinders Per Age (Same Batch)

  - Required Ages: 7, 14, 28, 56 and 90-Day

For Each Age: Plot each W/C Versus Average Flexural and Average Compressive Strength

Mix Design

Strength Testing

For Each Age: Plot Each W/C Versus Average Flexural and Compressive Strength

- Using Graphs: Determine W/C Equal/Exceeds Required Average 90-day Flexural Strength: 5.55MPa (805 PSI)

- Using Selected W/C and Graphs: Determine Expected Flexural and Compressive Strengths at the Required Ages For Mixes

Mix Design Testing

Correlation Ratios Determinations

- For Selected Mixture:

- Ratio 14-day Compressive To 90-day Flexural Strength (Acceptance)

  - 14-day Compressive = 4000 psi

  - 90-day Flexural = 805 psi

  -Ratio Calculation: 4000 / 805 = 4.97

Mix Design Testing

Correlation Ratios Determinations

- Ratio 7-day Compressive To 90-day Flexural Strength (CQC Control)
  - 7-day Compressive = 3400 psi
  - 90-day Flexural = 805 psi

  Ratio Calculation: 3400 / 805 = 4.22

Other Design Testing

- Not Required But Beneficial
  - Set Time
  - Bleeding of Concrete
  - Unit Weight
  - Vary Dosages of Admixtures
    - Paving Seasons (Summer / Fall)

Concrete Materials Incompatibility

- Problems that may develop
  - Early stiffening
  - Excessive retardation
  - Poor air void system
  - Early age cracking – excessive shrinkage
- Affected by ambient temperature – no problems at one temperature, but problems at another temperature
- Potential causes
  - Higher potential with use of supplementary cementing materials & 2 or 3 admixtures

Mix Design Study Report
Multiple Batches

MIX PROPORTIONING STUDIES						
DESIGN/BUILD REPLACE AIRFIELD RAMP - KIRTLAND AFB						
Design	**26-.4**	**26-.45**	**26-.5**	**27-.4**	**27-0.45**	**27-.5**
Batch Date	10/13/00	10/03/00	10/11/00	10/13/00	10/16/00	10/16/00
w/c ratio	0.4	0.45	0.5	0.4	0.45	0.5
Mix Proportions (pcy)						
Cement	433	388	347	461	410	369
Fly ash	144	129	116	154	137	123
Blended Sand	1401	1525	1587	1345	1452	1540
Size #4 aggregates	323	319	306	334	324	316
Size #67 aggregates	1237	1222	1173	1253	1218	1188
Water	231	230	231	246	246	246
Air Entrainment (oz)	17	19	12	11	10	9
Water reducer (oz)	23.1	20.7	18.5	24.6	21.87	19.68
Properties						
Slump (in.)	1	0.75	1	2.25	2.25	2.5
Air Content (%)	6.5	6.4	5.5	6.2	6.4	6.5
Unit Weight (pcf)	139.4	140.9	137.7	137.7	139	136.8
Conc. Temp. (deg. F)	71	76	64	69	72	70
Air Temp. (deg. F)	63	70	57	60	58	52
Compr. Strength (psi)						
3 days	1853	2023	1207	1917	1983	1576
7 days	2668	2897	1958	2963	2612	2235
14 days	3180	3378	2507	3642	3218	2727
28 days	4057	4225	3297	4415	3803	3377
90 days	4467	5243	3737	5213	4717	4382
Flexural Strength (psi)	**Required @ 90 days= 750 psi**					
3 days	380	370	290	360	380	370
7 days	520	472	370	533	435	398
14 days	588	568	438	610	517	468
28 days	667	653	540	650	608	553
90 days	762	720	602	795	703	627

Trial Batch Summary Report

6200 psi @ 48 days	Trial Mix ID:	2853 Trl 3		2853 Trl 4		2853 Trl 5	
	Title:	w/c= 0.44		w/c=0.49		w/c=0.54	
	Batch Date:	11/10/2003		11/10/2003		11/10/2003	
Material Proportions per CY	Specific Gravity	Weight lbs. (1)(2)	Volume cf.	Weight lbs. (1)(2)	Volume cf.	Weight lbs. (1)(2)	Volume cf.
Rio Grande Type I-II Cement, lbs.	3.15	448	2.28	391	1.99	363	1.85
4 Corners Class F Fly Ash, lbs.	2.02	149	1.18	131	1.04	121	0.96
Water	1	263	4.21	257	4.12	262	4.20
Southway Los Lunas, WCS (SSD)	2.59	1105	6.84	1156	7.15	1247	7.72
Southway Los Lunas, Sz#4 CA (SSD)	2.75	326	1.90	312	1.82	317	1.85
Southway Los Lunas, Sz#67 CA (SSD)	2.73	1329	7.80	1278	7.50	1290	7.57
Southway Los Lunas, Sz#8 CA (SSD)	2.78	275	1.59	264	1.52	266	1.53
Water Reducer, MB Polyheed 997, oz.	-	39.6		52.1		7.3	
Air-Entraining Agent, PaveAir 90, oz.		5.1		6.8		5.1	
Aggregate Correction Factor		0.6		0.6		0.6	
Air Content, % (5)	-	4.4	1.20	6.9	1.87	4.9	1.33
			27.00		27.01		27.01
Plastic Properties							
Slump, in. (4)		3.00		3.00		3.25	
Ambient Temperature, deg. F (4)		69		69		69	
Concrete Temperature, deg. F (4)		70		70		70	
Cementitious Content, pcy		597		522		484	
Fly Ash-to-Total Cementitious, % (3)		25.0		25.1		25.0	
Water/Cementitious Ratio (3)		0.44		0.49		0.54	
Fine-to-Total Aggregate, %(wt.) (3)		77.2		78.7		79.7	
Apparent Air Content,% (4)		5.0		7.5		5.5	
Air Content, % (5)		4.4		6.9		4.9	
Measured Unit Weight, pcf (4)		146.0		141.4		144.8	
Theoretical Unit Weight, pcf (2)(3)		143.4		139.4		142.3	
Target Air Content, %		5.0		5.0		5.0	
Compressive Strength, psi							
Standard Cured Specimens							
@ 3 days		3640		2560		1990	
@ 7 days		4500		3250		2700	
@ 14 days (6)		5140		3757		3403	
@ 28 days (7)		5860		4290		4110	
@48 days (8)		6446		4719		4521	

Notes:
(1) units in lbs. unless stated otherwise
(2) proportions based on measured air content
(3) as calculated
(4) as measured
(5) (Apparent Air Content-Agg.Correction Factor)
(6) average of 3 specimens
(7) average of 2 specimens
(8) Projected 48 days based on assumed 28/48,SGR =1.10

Compressive Strength Summary Report

Concrete Laboratory Trial Batches
Compressive Strength Data Summary

Project:	Munitions Storage Mix Design	**Date:**	12/10/03
Client:	A.S.Horner	**Amended:**	
Job No:	3-519-002853	**By:**	Vishal
Lab No:			

Trial Mix ID:	2853 Trl 3	2853 Trl 4	2853 Trl 5
Title:	w/c= 0.44	w/c=0.49	w/c=0.54
Batch Date:	11/10/2003	11/10/2003	11/10/2003
3 Day Compressive Strength Data			
(F10) Test Date	11/13/2003	11/13/2003	11/13/2003
Specimen 1, psi	3640	2560	1990
Specimen 2, psi			
Specimen 3, psi			
Average, psi	**3640**	**2560**	**1990**
7 Day Compressive Strength Data			
Test Date	11/17/2003	11/17/2003	11/17/2003
Specimen 1, psi	4500	3230	2700
Specimen 2, psi		3270	
Specimen 3, psi			
Average, psi	**4500**	**3250**	**2700**
14 Day Compressive Strength Data			
Test Date	11/24/2003	11/24/2003	11/24/2003
Specimen 1, psi	5070	3680	3420
Specimen 2, psi	5260	3800	3410
Specimen 3, psi	5090	3790	3380
Average, psi	**5140**	**3757**	**3403**
28 Day Compressive Strength Data			
Test Date	12/08/2003	12/08/2003	12/08/2003
Specimen 1, psi	5740	4140	4010
Specimen 2, psi	5980	4440	4210
Specimen 3, psi			
Average, psi	**5860**	**4290**	**4110**

Three Trial Batches

Flexural Strength Report

MRM

Construction Services, LLC
2636 S. 20th Place Phoenix, AZ 85034
(602) 340-0378 fax (602) 340-0487

SAMPLE NO: TCO-3 Report No: _____ Lab No

PROJECT NAME: **DMAFB**
MRM PROJECT NO: **Mix Design**
CLIENT PJT. NO.: 110366
DATE SAMPLED: 5/1/2003
SHIFT:

LOCATION:
STATION:

SUPPLIER:	Sundt	BATCH SIZE:	21cf	CONC. TEMP:	70
MIX ID:	TWCO-3	BATCH TIME:	6:00 p.m. AM / PM	AMB AIR:	73
STRENGTH	700 @ 90 psi	SAMPLE TIME:	6:15 p.m. AM / PM	SLUMP:	2"
TICKET NC	n/a	SAMPLED BY:	Lab	% AIR:	4.7
UNIT WT:	142.9 pcf	YIELD:	n/a	W/C RATIO:	0.40
SPECIMENS DELIVERED TO LAB BY:		Cast at Lab		DATE:	n/a

FLEXURAL STRENGTH TEST RESULTS
SPECIMEN SIZE: 20 in. x 6 in. x 6 in. BEAMS
T 97; ASTM C 78 and C 42C/42M

SPECIMEN NO.	TEST DATE	AGE (DAYS)	MAX LOAD	FLEX STRGTH	BREAK TYPE	AVG	AVG. LEGNTH	AVG. WIDTH
1	5/29/03	28	8280	680	Good		18"	6.046
2	5/29/03	28	8580	730	Good		18"	6.030
3	5/29/03	28	8580	710	Good		18"	6.034
4	5/29/03	28	8400	700	Good		18"	6.023
5	5/29/03	28	7680	630	Good		18"	6.063
6	5/29/03	28	7980	660	Good	685	18"	6.016
7	7/30/03	90	8820	740	Good		18	6.019
8	7/30/03	90	9060	730	Good		18	6.083
9	7/30/03	90	9960	800	Good		18	6.205
10	7/30/03	90	9360	760	Good		18	6.170
11	7/30/03	90	8880	720	Good		18	6.089
12	7/30/03	90	10080	840	Good	770	18	5.986
13								
14								
15								

TESTED BY:	M.T.	GE		REVIEWED BY:	MT
DATE:	29-May-03	30-Jul-03		DATE:	30-Jul-03

REMARKS:

Single Batch Test Data

Compressive Strength Report

VRM

struction Services, LLC

S. 20th Place Phoenix, AZ 85034

0378 fax (602) 340-0487

SAMPLE NO.	TCO-3	LAB NO	78
PROJECT NAME:	DMAFB		
PROJECT NO:	Mix Design #3		
REPORT NO:			
DATE BATCHED	5/1/03		
LOCATION:	Lab		

Sundt	BATCH SIZE:	21cf	CONC TEMP	70 F
TWCO-3	BATCH TIME:	6:00 p.m.	AMB AIR	73 F
H: 700 Flex @ 90 days	SAMPLE TIME:	6:15 p.m.	SLUMP	2" in.
O: n/a	SAMPLED BY:	Lab	% AIR	4.7 %
142.9 pcf	YIELD: n/a	c.yds	H20 ADDED:	0

D TO LAB BY: Cast at Lab DATE: n/a

ylinders 6 6 X 12 T-22-92, C-39-96

ylinders X T-106, C-109

CONCRETE CYLINDERS COMPRESSIVE STRENGTH TEST RESULTS

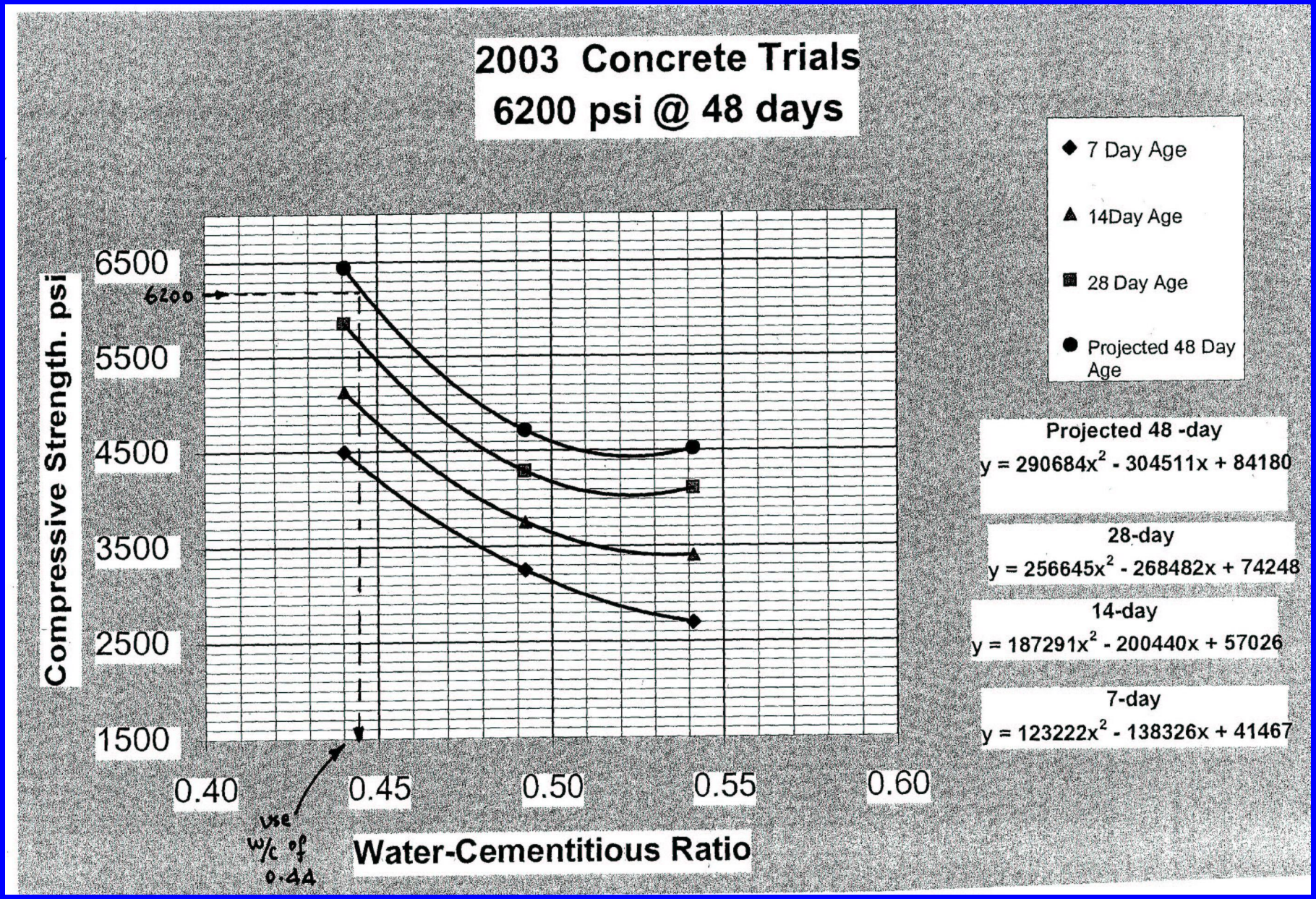
SPECIMEN NO.	TEST DATE	AGE (DAYS)	MAXIMUM LOAD (LBS)	COMPRESSIVE STRENGTH (PSI)	BREAK TYPE	AVERAGE
1	7/30/03	90	178,950	6330	shear	
2	7/30/03	90	173,460	6140	shear	
3	7/30/03	90	183,710	6500	shear	
4	7/30/03	90	179,600	6350	shear	
5	7/30/03	90	182,320	6450	shear	
6	7/30/03	90	176,990	6260	shear	6340
7						
8						
9						

ESTED BY:	REVIEWED BY:
ATE:	DATE:

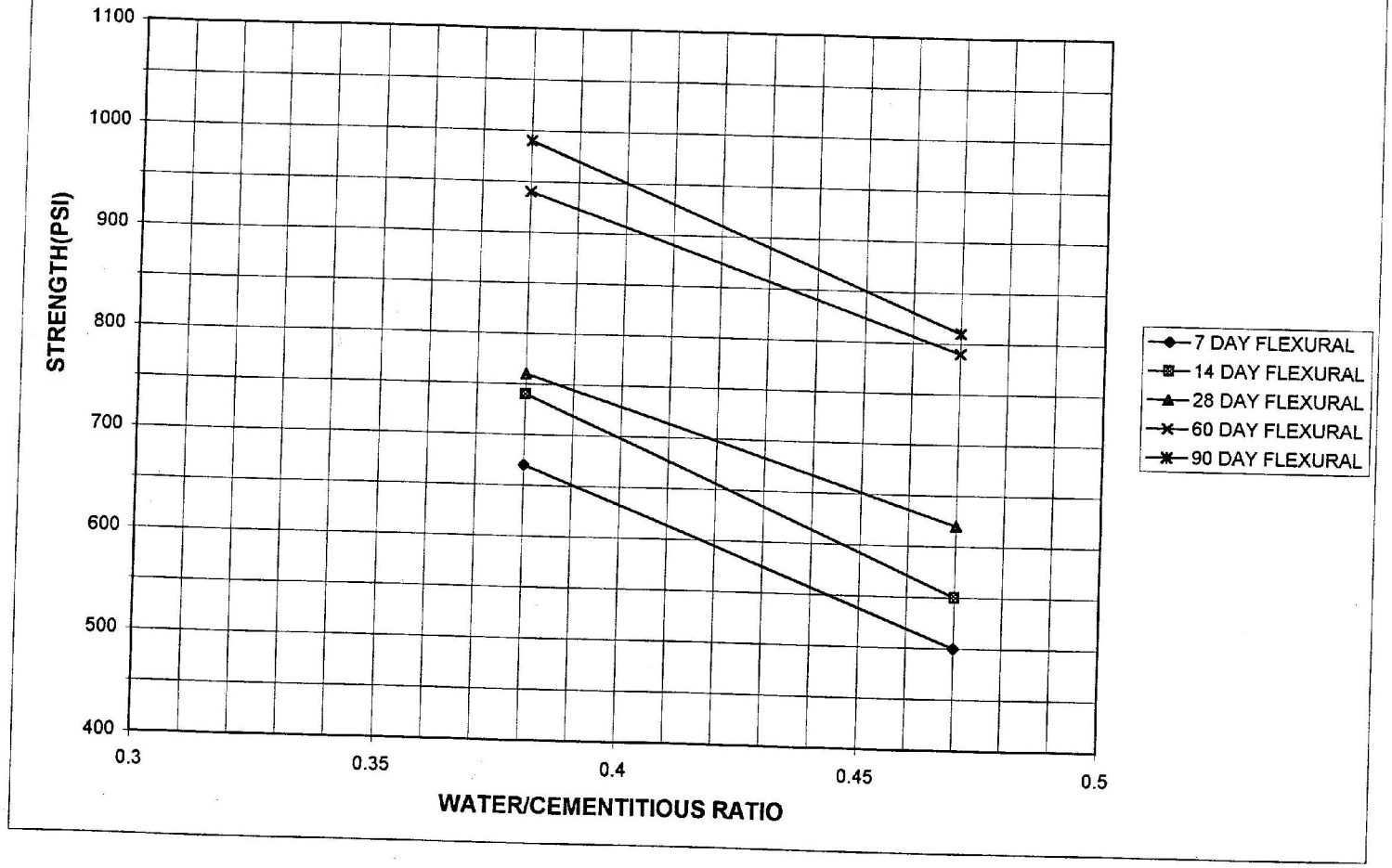
ROSS SECTION END AREA OF CYLINDERS: 4"X 8" = 12.57; 6" X 12" = 28.27

Single Batch Test Data

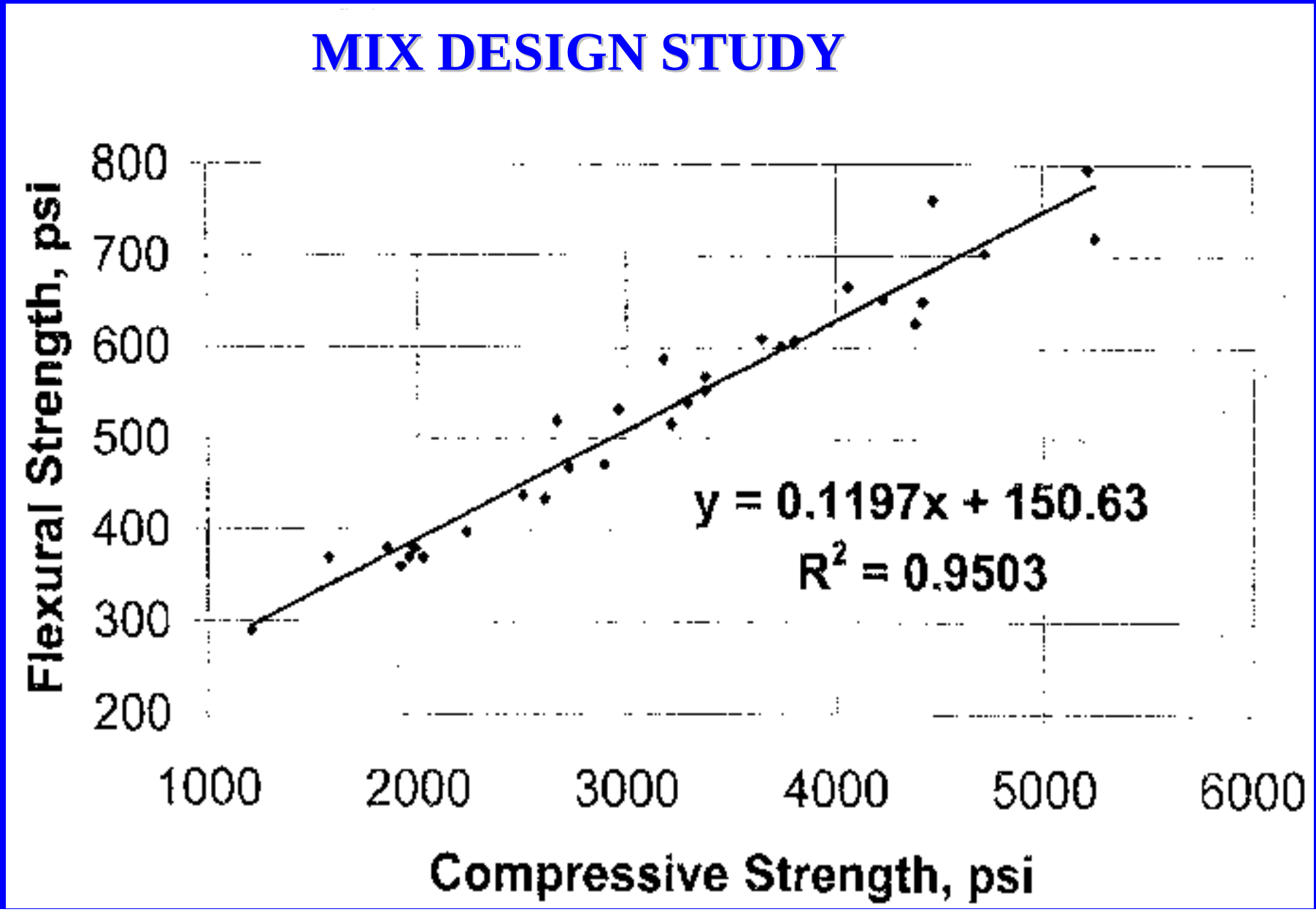
W/C vs Compressive Strength



W/C+P vs Flexural Strength



Flexural Strength vs Compressive Strength



Specified Strength vs Required Strength Option

- Mix Design May Be Submitted Based On Historical Performance (Current To Within 1 Yr.)

- Statistical Analysis

- Overdesign To Accommodate Batch -To - Batch and Within Batch Variation

Field Control of Mixtures

- Variations in Materials, Weather, and Other Conditions Can Produce Variations in Slump and Air Content

- Production Control is Essential

- Review of Production Test Data

- Review Mill Test Reports

Field Control of Mixtures

- Actions to Minimize Fresh Property Variations
  - Make Accurate Moisture Corrections
  - Keep Aggregate Grading Uniform
  - Adjust Air-Entraining Admixture
  - Verify Specific Gravity

Minor Adjustments Of Mix Design Will Likely Have To Be Made During Production.

Important To Identify The Person Authorized To Make Adjustments.

QUESTIONS??